If Only Wood Could Speak...

Explorations in digital fabrication processes based on timber grain and patterns

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This paper presents an exploration following wood patterns applied to traditional woodworking techniques such as steam bending and carving. It builds on a digital fabrication process where the patterns that are unique to each wood strip and which constitutes their structural geometry are also used within fabrication processes and applied machinery such as the zund machine. The experiments were done in two series where the earlier set focuses on routing along the wood patterns of thin wood strips and steam bending the different pieces. The second set experimented with carving thick wood strips on passes generated from the extracted patterns. An automated technique based in computer vision and specifically OpenCV was developed using different filters in order to extract the patterns and transfer the results into CAD software where the lines where further manipulated for variable exploration. The results of this study led to a better understanding of wood patterns from a geometrical perspective thus enriching the aesthetic composition of a design while being authentic to the unique nature of each piece of wood.

Keywords: *Timber, pattern recognition, grain, image, carving , digital fabrication*

INTRODUCTION

The direction of grain in timber boards depends highly on the form and growth of the source tree trunk in addition to the direction of the cut. Manipulating wood boards follows several techniques were none take really into account the organic natural patterns that timber has. The current techniques used in fabrication of timber usually impose geometries on the board's face such as kerf cutting techniques to achieve the bending of thick timber boards or the process of applying small patterns to achieve more flexibility. This research explores the potential of tracking the direction of grains in timber boards from pattern recognition to automated transfer of these lines into digital design tools, such as rhino, then sending the image again into the physical world through the application of these patterns onto the board it was extracted from. The combination of form finding techniques versus digital application lead to results interesting transferred into physical

fabrication.

RELEVANT WORK

Among the researches happening in the architecture and fabrication fields and focused on woodwork techniques are the research projects con-ducted by Achim Menges in addition to the exploration done by the Living Studio.

The Kerf-based complex wood systems research project conducted within Achim Menges' studio at the Harvard Graduate School of Design "performative wood studio" and which is building on kerf cutting to pro-duce a systemic structure is one of the examples working with the varia-tion of orientation of carving to achieve an optimized bending. Wood be-ing an anisotropic material, it's stronger along the grain than across it which means it's possible to cut across the wood strip without affecting the structure strength.The study focuses on strategic local weakening of the wood strips by disrupting the continuity of the fibre through kerf cutting techniques. The process explores the computational manipulation of the kerf depth, length, frequency and orientation in order to achieve an elaborate bending and warping of the various elements. The accumulation of multiple kerf within a wood slat modifies the bending behaviour of the wood once it is steamed. The usual way in applying kerf cutting at constant depth results in stress concentration at the end of the kerfed length and produces kinks. The vari-ation in kerf depth allows for the calibration of bending stiffness with the material removal.

For this purpose, the group working on the project custom-designed a rota-ry saw tool for a 6 axis robot to test the process parameters (ie: blade revolution, climb cutting, feed rate etc) in relation to geometric kerf parameters (depth, length, frequency, orientation). The integration of this complex process, led to the design and fabrication of a large scale proto-type showcasing the different characteristics studied. (Menges et. Al)

Another research project conducted by The Living Studio is based on automating knots' recognition within wood planks where such pieces are usually discarded or not favoured in finishes which leads to a lot of wasted material. The project aims to reduce this waste by providing a solution based in digital fabrication whereas through machine learning the knots are detected. The information is then transferred to a CNC -sandblasting ma-chine to expose the micro-contours at the knots. As a proof of concept for this study, a solar energy study was done on a façade during the design process and then the produced wood planks where organized throughout the elevation to match this analysis in order to apply targeted thermal insu-lation within the micro contours.

MATERIALS AND METHODS
Materials

Timber is the main material used in the following experiments whereas the grains determine the direction of the patterns, which are the main focus throughout the tests. Wood rings within a tree vary between dark and light patterns as the effect of the seasonal change. These patterns are divided into summerwood and springwood forming the annual ring. Springwood is the "softer more porous portion of an annual ring of wood that develops early in the growing season" while summerwood is a harder less porous portion which develops late in the growing season.The patterns on a timber board are defined by its location in the tree trunk and the direction of sawing. The most known cutting styles are the flat sawn, quarter sawn and rift sawn.The flat sawn cut leads to the cathedral pattern with the rings intersecting with the board face between 0° and 35° and is the most common while be-ing the cheapest. The quarter sawn has the rings intersect with the board face between 65° to 90° and gives a linear pattern while being more expensive than the flat sawn. The rift sawn timber board has the rings intersecting between 35° to 65° and it usually leads to a linear pattern while being the most expensive and least common since it generates a lot of wasted wood.

Methods

A combination of traditional methods in manipulating timber are used within the following experiments such as steam bending, kerf cutting and pattern cutting.Steam bending is a woodworking technique that involves a lot of consideration to the direction of the wood grain and where the wood strips are steam heated in a box. The application of heat and moisture on the wood would make it pliable and easy to bend whether on a prepared form or through free form curves or shapes. Wood cells are kept together with a substance called lignin which loses partially its strength when subjected to steam thus allowing the wood to bend.Kerf is a term normally used to refer to the width of a cut made by a sawblade. Kerf cutting is the execution of several kerf along a piece of wood. In boat construction, furniture design, musical instrument and many other fields, regular kerfing is one of the main techniques to have the wood bend in one direction.For this study, wood patterns were first extracted manually by drawing the lines with a CAD software in the first set of tests. In the second set of tests the patterns were extracted through an automated process then the bending was done with an wood iron (figure 4) while the carving was done with a routing machine specifically Zünd's model G3 with the Router Module (RMA) (figure 5)

EXPERIMENTAL DESIGN
First set of tests

The earlier tests were conducted on 2.5 mm thick wood where the wood pat-terns were manually drawn using a CAD software after importing a picture of the wood plank. After this step the wood would be taken to the zund machine which routes along the pattern lines.Using this method, three tests were done on three different wood board and according to the following variation:

1. Test 1.A(figure 6) Routing along a cathedral patterned wood board then applying steam bending along the formed surfaces.
2. Test 1.B (figure 7) Routing along the wood patterns then manual steam bending
3. Test 1.C (figure 8) Routing along the wood patterns while alternating the carving between both edges.

Figure 1
Test 1.A

Figure 2
Test 1.B

Figure 3
Test 1.C

Figure 4
The original picture
of the wood slat

Figure 5
Picture after the
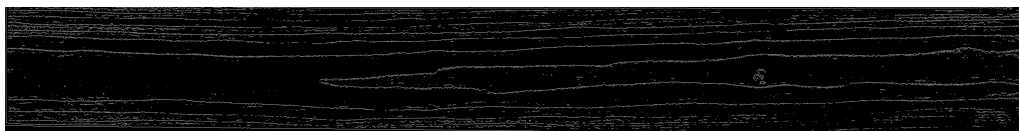application of the
blurring filter

Figure 6
Extraction of the
patterns after the
cv2canny filter
application

Figure 7
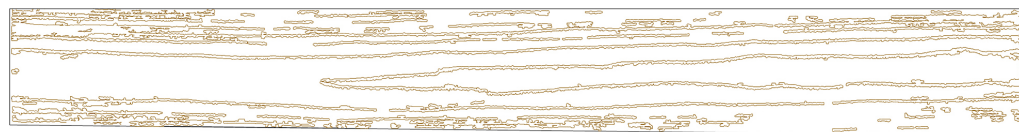Application of the
dilate filer

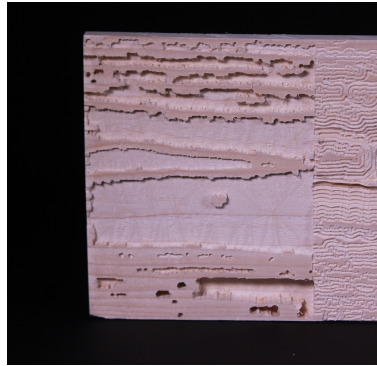

Figure 8
Extracted .dxf file
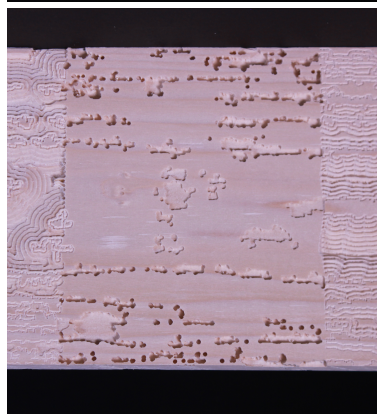
Figure 9
Test 2.A

Figure 10
Test 2.B

Figure 11
Test 2C

The manual steam bending of the wood strips started first by soaking the slats in water then wrapping those slats in aluminium before using the wood iron. The purpose of aluminium was to keep the wood humid enough during the contact with the iron which leads to the evaporation of the water and thus to a limited manipulation of wood. After applying the necessary pressure for the bending when in contact with the iron, the pressure is kept until the wood cools down.Observations:1-when cutting along the patterns and bending, we are releasing this part of the wood from the tensions at that point2- when routing on the pattern of the wood, it matches one face of the wood while it misaligns on the back face due to the direction of the grains within the tree trunk

Observations:.

1. when cutting along the patterns and bending, we are releasing this part of the wood from the tensions at that point.
2. when routing on the pattern of the wood, it matches one face of the wood while it misaligns on the back face due to the direction of the grains within the tree trunk.

Second set of tests

The second set of tests were done on a 1.5 cm thick timber board with au-tomated detection of wood patterns followed by the execution of different types of carving. The automated process of edge detection was done with an algorithm using computer vision tools and specifically openCV filters. Python is the programming language used within the process of building the algorithm.After a picture of the timber board is grabbed, the code will execute a series of steps going from blurring the image to reducing the noise (figure 10), then running the canny tool to extract the patterns (figure 11), then a dilate filter is applied to thicken the contours so the non-detected pixels or the unclosed lines would intersect (figure 11). Then the image goes through a vectorizing filter and it is saved in .dxf format which makes it possible to be imported into rhino where other digital fabri-

cation decision can be made according to the experiment to be run.

Using this method, four tests were run on the same timber board cut out from a poplar tree in order to show the behaviour of the patterns and the transition from a method to another:

1. Test 2.A (figure 9): Carving the negative areas of the wood while keeping the dilated line not carved

2. Test 2.B (figure 10): offsetting a 2mm the lines from the closed surfaces on rhino and carving with the E7 tool (pointed bit) on the generated lines with a 0.5mm incremental depth.

3. Test 2.C (figure11): carving on the positive dilated patterns directly produced by the code without applying any other offset

4. Test 2.D (figure12): offsetting a 2mm the lines from the closed surfaces on rhino and carving with the R202 (flat end bit) on the generated
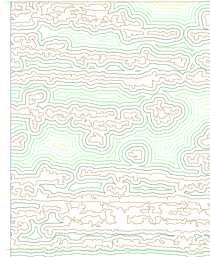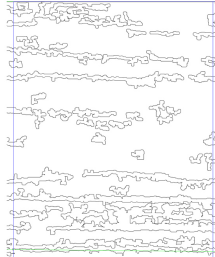

Figure 12
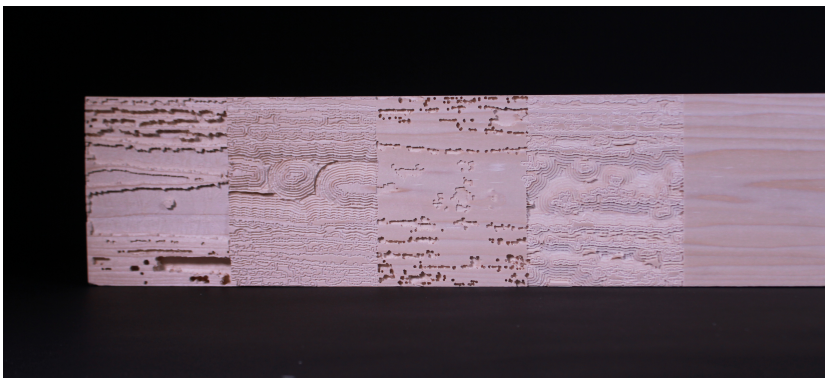Test 2.D | Between
fabrication and
CAD drawings

Figure 13
The four tests
visualized together
showing the
pattern's continuity

lines with a 0.5mm incremental depth.

Observations:.

1. The reading of a thick piece of wood should happen in relation to the different sides since the pattern changes in direction as we carve inside the wood board and this direction can be estimated approximately according to the lines on the sides of the timber board hence whenever the board is carved following the patterns, it's possible to carve incrementally following the direction guided by the continuity of the lines on the sides.

CONCLUSION

This research applies several tests where traditional ways of manipulating wood from carving to bending are explored within the scope of following the unique patterns of each wood board through the application of computer vision techniques to extract the lines and take them through digital fabrication processes to apply them again on the actual physical board it was extracted from.The major unique aspect of this research relies on following the natural organic patterns constituting the wood as a material which is not explored yet as a channel of fabrication while the most occurrent techniques impose either a linear pattern to achieve a geometry or a series of patterns also imposed to reach a flexible material.The outcome of this research can be applied within different fields ranging from architecture and specifically façade design involving wood louvers were bending wood is applied sometimes to optimize on the infiltration of sunlight within the internal space. Other applications of the outcome of this research include the design of wood pavilion, furniture design and yacht design where the mentioned industries have the carving and bending techniques already in-tegrated within the application.Finally many potential future research can build on those experiments such asthe application of the patterns withdrawn from wood into other materials in addition to working on incremental following the carving or prediction of the direction of the pattern happening on the sides of the wood board as well as joining both processes of carving then bending.

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